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Report

THE SOUND INSULATIONS OF METAL-FRAMED PARTITIONS HAVING STRUCTURAL LOADBEARING PROPERTIES

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Research and Development Department
Engineering Division
THE BRITISH BROADCASTING CORPORATION

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Summary

The sound insulations were measured of several single and double leaf partitions. The partitions had metal frames and were capable of supporting significant structural loads. The purpose of the work was to design structural partitions that were cheaper to build than the existing masonry walls used for the construction of large studios. For some of the double leaf tests, one of the leaves was blockwork and the other was metal-framed; for the remainder of the double leaf tests, both leaves were metal-framed.

Each of the partitions tested was suitable for use in different types of studio construction. The addition of glass wool insulation batts to the cavities of the partitions resulted in large increases in the measured sound insulations. The glass wool damps the motion of the boards and absorbs sound that has been transmitted into the cavities. The levels of sound insulation achieved from the partitions should be adequate for certain types of low cost studio construction. The partitions are considerably lighter than masonry walls. Therefore, the loadbearing requirements of the surrounding building will be reduced. Provided that the reductions in sound insulations are acceptable, the potential cost savings resulting from the use of lightweight structural partitions rather than masonry walls are very large.

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1. INTRODUCTION

Existing BBC designs for metal-framed partitions[1,2,3] are essentially non-structural. Thus, they are only suitable for the construction of small studios where relatively small loads are supported on the partitions (such as from acoustic treatment fitted to the walls and from wood wool cement slab ceilings supported on the tops of the partitions).

A source was located of steel studs suitable for the construction of lightweight structural partitions, with heights exceeding 6 m. These partitions could be used instead of the masonry walls that are typically used in the construction of large studios such as television studios. The structural partitions are capable of supporting floors carrying significant live and dead loads. The potential savings in building costs and construction time are large.

This Report describes sound insulation measurements made in the Research and Development Department Transmission Suite on a number of different designs of structural partition, intended for different applications. The work was undertaken as a collaborative project with British Gypsum, who supplied the materials and labour for the construction of the partitions, free of charge.

2. CONSTRUCTION DETAILS

The sound insulations were measured of two different types of structural partition. For the first set of partition tests, one leaf was made from dense concrete blocks and the other leaf had a metal-framed construction. For the second set of tests, all leaves were of metal-framed construction.

The blockwork wall was built into the aperture in the receive room walls. A 6 mm thick layer of rubber insulation sheet was used as a vibration break between the receive room walls and the blockwork wall.

The masonry wall was constructed from 450 × 225 × 140 mm dense concrete blocks. These blocks are often used in modern building construction. The blocks had a density of 2000 kg/m^3 amd a crush resistance of 7 N/mm^2. Care was taken to ensure that all joints between blocks were fully filled with mortar to ensure that no leakage paths were present. For some of the tests, the wall was rendered on one side, and for others, it was rendered on both sides. The render thickness was 15 mm.

For the first test, the blockwork leaf was built after the lightweight leaf had been constructed. The cavity between the blockwork and lightweight leaves was filled with 50 mm-thick glass wool batts. The batts were fitted before placing the blocks, to ensure that no mortar was trapped in the cavity, which might have resulted in an acoustic bridge.

The second leaves of double leaf partitions were constructed in the opening in the source room walls. This ensured that the two leaves of the partition were structurally independent, which simulates the way they would be mounted in practice.

For reference, Fig. 1 shows the symbols used in the keys to all the subsequent measurement graphs.

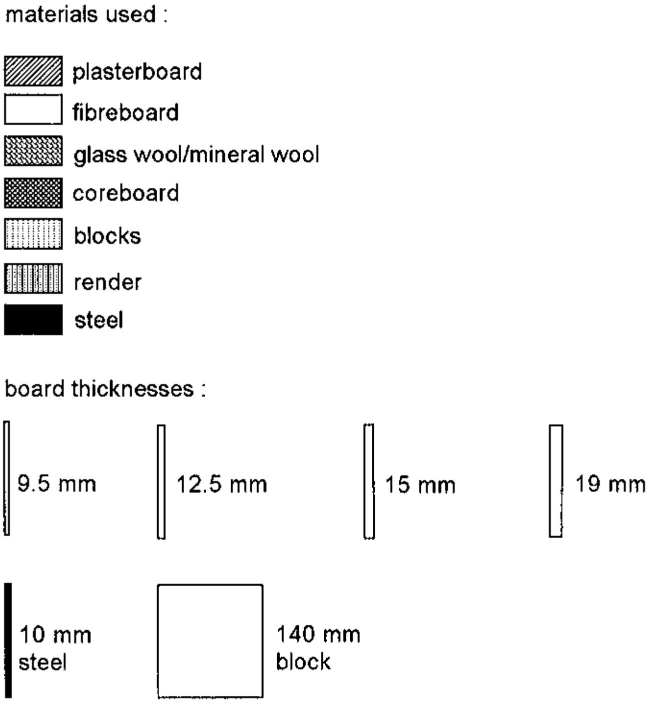

Fig. 1 - Symbols used in the keys for the graphs.

3. PARTITIONS WITH ONE BLOCKWORK LEAF AND ONE LIGHTWEIGHT LEAF

3.1 A partition containing a structural Camden

The 'Camden' is a lightweight partition used in BBC studio construction. It has a high level of sound insulation for its weight. It consists of studding clad with a layer of 12.5 mm fibreboard each side, followed by a layer of 12.5 mm plasterboard each side. The internal cavity width is typically 70 - 75 mm. Most Camdens presently installed are timber-framed[4]. Recently, there has been a move towards the use of partitions having metal frames[1].

Fig. 2(b) shows the measured sound insulation of a partition consisting of a structural metal-framed leaf, spaced 50 mm from the 140 mm blockwork wall. The lightweight leaf had to be constructed first because boards had to be screwed onto both sides of the leaf. This type of construction is similar to that which the structural stud manufacturer recommends for normal building construction, except that it contains fibreboard. The lightweight leaf, which is a structural equivalent to the Camden, consisted of 100 mm-thick structural studs, clad each side with a 12.5 mm layer of fibreboard, followed by a 12.5 mm layer of plasterboard. The cavity between the two leaves was filled with 50 mm-thick glass wool batts.

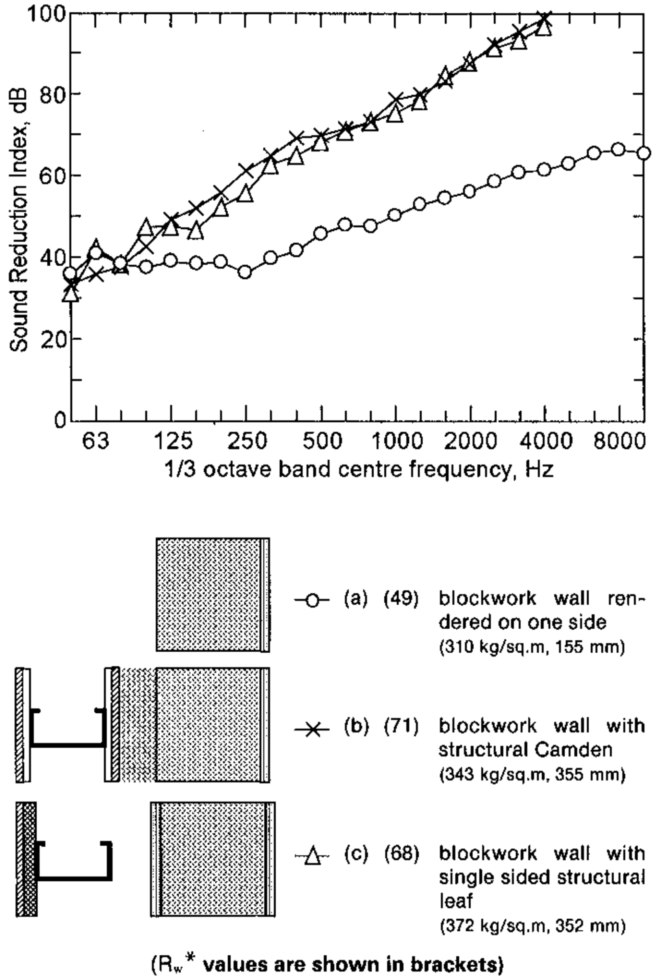

Fig. 2 - The sound insulation of a structural partition containing fibreboard.

Because the blockwork leaf was constructed last, it could only be rendered on one side.

The measurement is compared with that of the 140 mm blockwork wall — Fig. 2(a) — (rendered on one side only) made after the lightweight leaf had been removed. (For reference, the Appendix details various sound insulation measurements made on the blockwork wall alone.) Also shown (Fig. 2(c)), for comparison, is a measurement (described in more detail later) of a partition consisting of a lightweight structural leaf spaced 50 mm from the 140 mm blockwork wall (rendered *both* sides). The lightweight leaf consisted of 100 mm thick structural studs clad on the outer side with a layer of 19 mm plank (boards mounted horizontally) followed by a layer of 12.5 mm plasterboard. This leaf has approximately the same mass as that of the structural Camden. (For reference, overall partition weights and thicknesses are included in the keys for the figures.)

The addition of the lightweight leaves considerably increased the measured sound insulations above 80 Hz. Despite some irregularity in the sound insulation curves above 80 Hz, the partition containing a structural Camden generally has a higher sound insulation than that of the partition having a lightweight structural leaf built from one side. This is probably because the partition containing a structural Camden has more internal damping and contains an absorbent layer of glass wool. The addition of the structural Camden actually reduced the sound insulations below 80 Hz. This is probably because the mass-air-mass resonant frequency[5] of the lightweight leaf is quite high. The resonant frequency of the single-sided leaf is lower than that for the structural Camden, because the cavity width between the two leaves is greater in the former partition. This accounts for the sound insulation of the partition with the single-sided leaf being lower at 50 Hz, but higher at 63 Hz, than that of the partition containing the structural Camden.

In the past, the BBC has used plasterboard and fibreboard together in partitions, because of the high insulation achieved for the relatively low weight. British Gypsum were unable to provide fire resistance or structural loading values for partitions containing fibreboard. Therefore partition designs using plasterboard alone were devised. These partitions were heavier than equivalent partitions containing fibreboard.

3.2 Partitions containing lightweight leaves built from one side

Fig. 3 shows the sound insulations of the remaining partitions tested that made use of the blockwork leaf. All the lightweight leaves were constructed from one side, after the blockwork leaf

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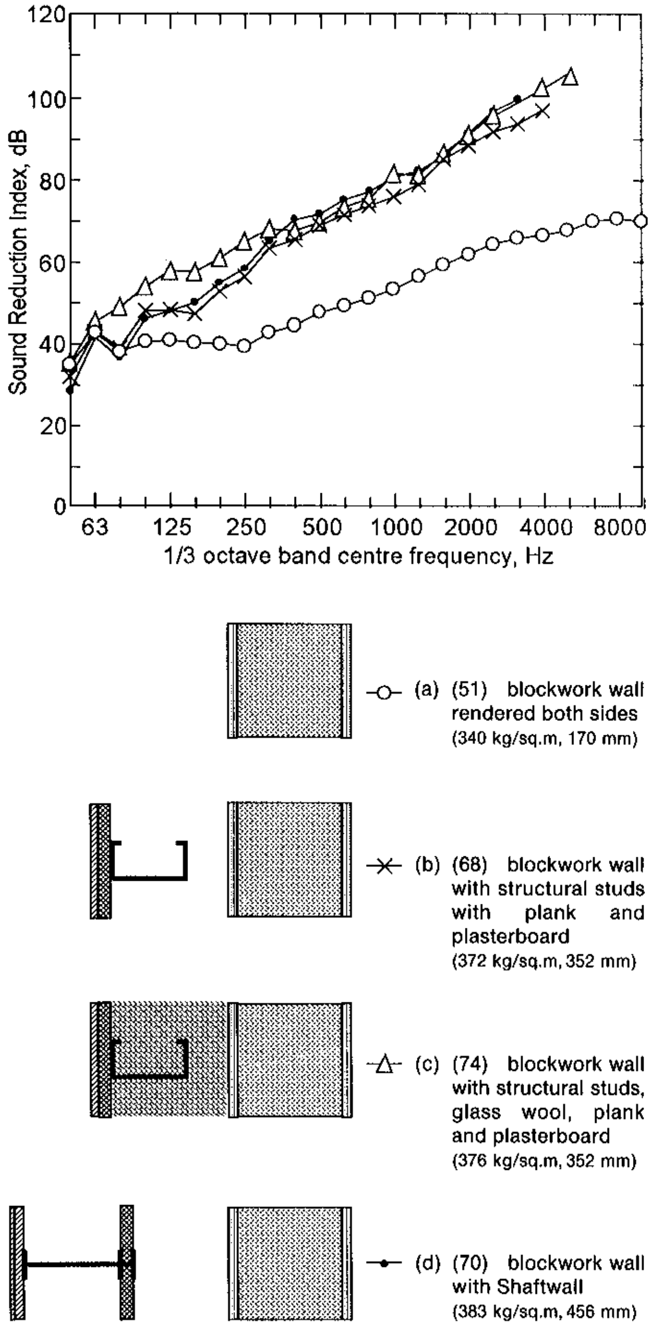
* As defined in BS 5821: Part 1: 1984.



(R_w values are shown in brackets)

Fig. 3 - The sound insulations of combined blockwork and metal-framed partitions.

had been built. The blockwork leaf had been rendered on both sides. For the partitions using 100 mm-thick structural studs (Fig. 3(b) and (c)), the cavity width was 50 mm. The 19 mm plank was fitted horizontally followed by the 12.5 mm plasterboard which was fitted vertically. The 19 mm plank and 12.5 mm plasterboard were selected for use in the lightweight leaf because they give an overall leaf weight comparable to that of a conventional metal-framed Camden. The thicknesses of the 19 mm plank and 12.5 mm plasterboard were also sufficiently different to reduce the effects of wave coincidence[6]. The fact that the boards were only clad on one side of the studs does not affect the load carrying abilities of the leaves, because the studs do not rely on the cladding materials for their strength.

For the partition containing a Shaftwall* leaf (Fig. 3(d)), the cavity width was 115 mm. The leaf was constructed from 150 mm-thick Shaftwall studs and the inner skin consisted of 19 mm coreboards. A layer of 15 mm plasterboard was screwed to the outers of the studs, followed by a layer of 9.5 mm plasterboard. These two layers of boards have a combined thickness equivalent to that of the one layer of plasterboard and the one layer of fibreboard, as used in the conventional Camden. The different board thicknesses were used to reduce the effects of wave coincidence.

The addition of the lightweight leaves increased the measured sound insulations above 80 Hz in all cases. The sound insulations of the partition with the Shaftwall leaf (Fig. 3(d)) above 125 Hz were higher than those of the partition made from structural studs (Fig. 3(b)). This is probably because the Shaftwall leaf is heavier than the structural metal-framed leaf, and because the separation between the Shaftwall leaf and the blockwork leaf is greater than that between the structural metal-framed leaf and the blockwork leaf. Below 125 Hz, the partition with the Shaftwall leaf had marginally lower sound insulations than that with the structural metal-framed leaf. The addition of the glass wool to the cavity of the partition containing structural metal-framed studs significantly increased the measured sound insulations above 63 Hz. The increase was most pronounced between 80 Hz and 250 Hz. The glass wool damps the motion of the boards and absorbs sound that has passed into the cavity.

Practically, the partition with a Shaftwall leaf is more complicated, wider, has a higher mass, and is structurally less strong than that containing structural metal-framed studs. It is intended for use in large studios where there are no significant loads to be carried. It can be built to a height of 7.5 m. The partition containing structural metal-framed studs has a wide cavity and the studs are exposed in the cavity. This may make the partition vulnerable to flanking transmission of sound, if sound can leak into the cavity at partition boundaries or at door and window details. The fact that the studs are exposed to the cavity may also have implications on the fire integrity of the partition. The partitions containing structural metal-framed studs were intended for use in large studios where heavy loads are to be carried.

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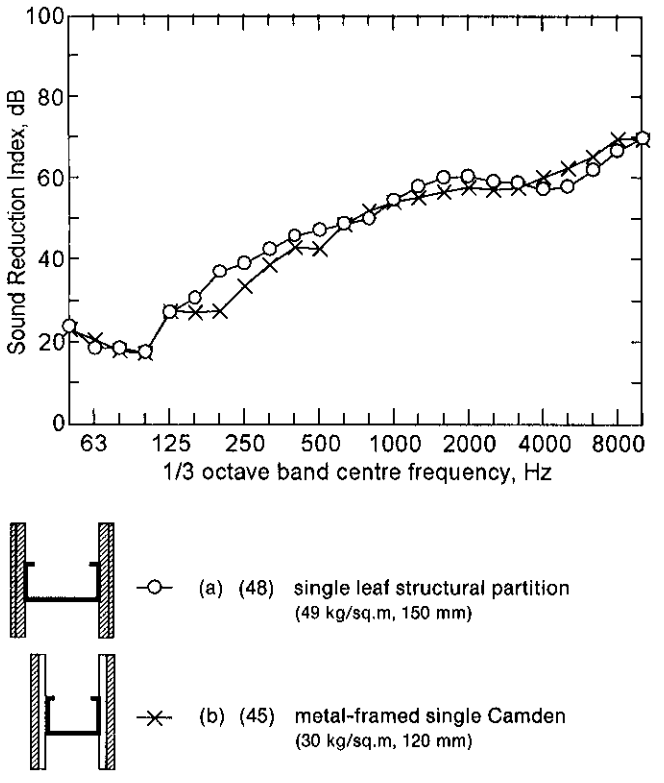
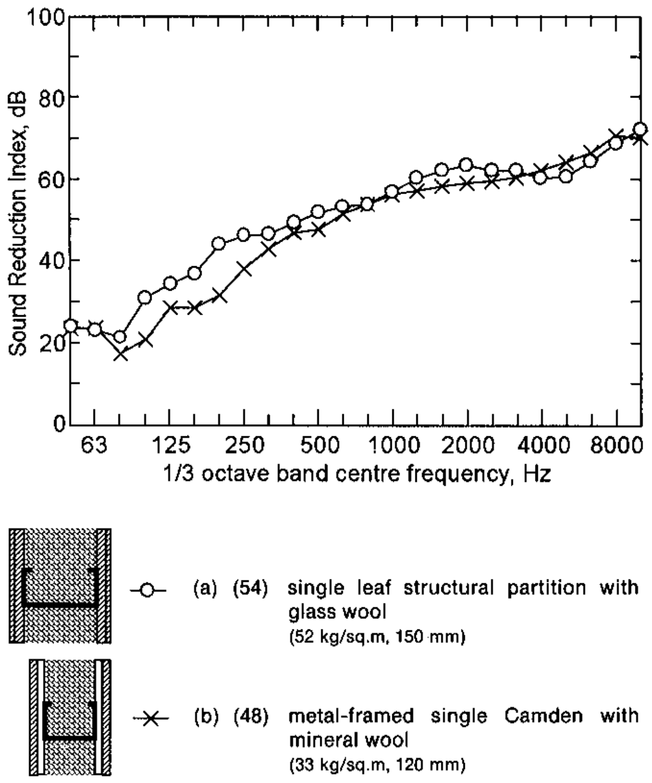
* A type of leaf which can be constructed from only one side.



(R_w values are shown in brackets)

Fig. 4 - The sound insulations of single leaf metal-framed partitions.



(R_w values are shown in brackets)

Fig. 5 - The sound insulations of single leaf metal-framed partitions with treated cavities.

4. PARTITIONS CONTAINING ONLY LIGHTWEIGHT LEAVES

4.1 Single leaf partitions

This Section describes sound insulation measurements made on two single leaf structural metal-framed partitions, one without acoustic treatment in the cavity and the other with acoustic treatment. The partitions were intended for use in intermediate-sized studios where heavy loads are to be carried.

Fig. 4(a) shows the measured sound insulation of a single leaf structural metal-framed partition. Structural metal studs (100 mm thick) were clad each side, first with a layer of 15 mm plasterboard, and then with a layer of 9.5 mm plasterboard. Also shown for comparison (Fig. 4(b)), is the sound insulation of a metal-framed single Camden. The structural partition has similar sound insulations to those of the single Camden between 50 Hz and 125 Hz, and between 630 Hz and 1 kHz. Between 160 Hz and 500 Hz, and between 1.25 kHz and 3.15 kHz, the sound insulations of the structural metal-framed partition are higher than those of the metal-framed single Camden. The width of the cavity of the structural metal-framed partition is 100 mm rather than 70 mm in the single Camden. Also, the double plasterboard layer has more mass than the plasterboard-fibreboard combination in the single Camden. This helps to explain why the sound insulations of the structural metal-framed partition are characteristically slightly higher than those of the metal-framed Camden.

Above 3.15 kHz, the structural metal-framed partition has lower sound insulations than those of the single Camden. This difference is related to wave coincidence. A partition containing double layers of 12.5 mm plasterboard has a pronounced dip in its sound insulation curve at 3.15 kHz - 4 kHz. Using different thicknesses of plasterboard (9.5 mm and 15 mm) reduces the depth of the dip, because the natural bending frequencies of the two thicknesses of board are different. However, with combined 12.5 mm plasterboard and 12.5 mm fibreboard, as in the single Camden, the natural bending frequencies of the two boards are even further separated, because the densities of the two boards are very different. Also, the fibreboard damps the motion of the plasterboard. These factors explain why the depth of the coincidence dip is greater for the 9.5 mm/15 mm plasterboard combination than for the 12.5 mm plasterboard and 12.5 mm fibreboard combination.

Fig. 5 shows the sound insulations of single-leaf partitions that are similar to those in Fig. 4, except that acoustic treatment had been installed in the cavities of the partitions. The cavity of the structural metal-framed partition (Fig. 5(a)) was filled with 100 mm-thick glass wool batts. The cavity of the metal-framed Camden (Fig. 5(b)) was filled with 75 mm-thick mineral wool batts. The sound insulations of the two partitions are similar between 50 - 63 Hz and 800 Hz -1 kHz. The structural metal-framed partition has lower sound insulations between 4 kHz and 8 kHz, because of wave coincidence effects. The porous layer does not significantly alter the effects of wave coincidence.

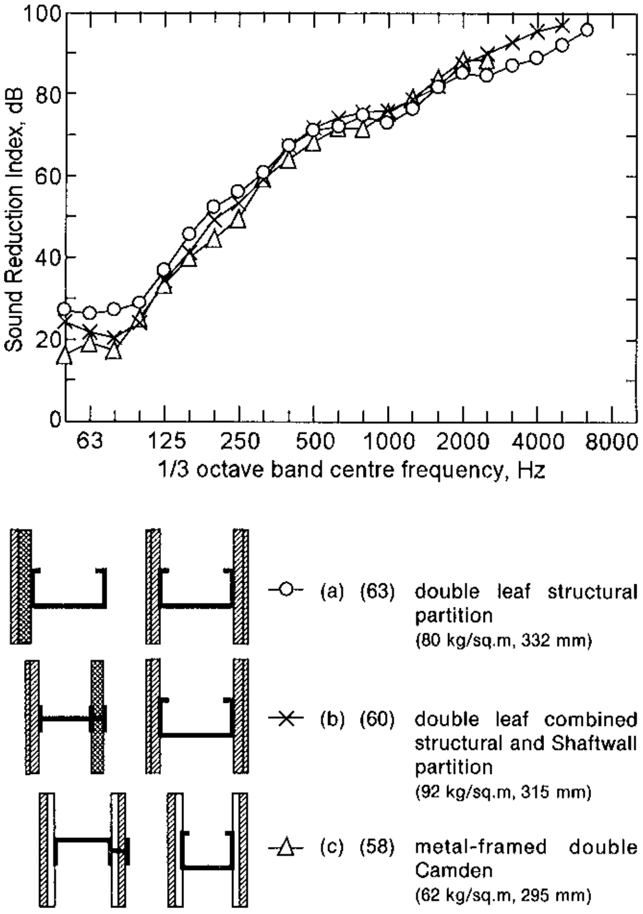
The structural partition containing the glass wool has considerably higher sound insulations between 80 Hz and 630 Hz, and between 1.25 kHz and 3.15 kHz, than the single Camden containing mineral wool. This is because the structural metal-framed partition has a wider internal cavity and more mass. The addition of glass wool to the cavity of the structural metal-framed partition had a greater effect on the sound insulations, particularly at lower frequencies, than the addition of mineral wool to the single Camden. The mineral wool and glass wool damp the motions of the boards and they acoustically treat the cavities. The fibreboard in the Camden also performs these functions. This explains why the addition of glass wool to the cavity of the relatively undamped structural metal-framed partition has a significant effect on the measured sound insulation; whereas the addition of mineral wool to the cavity of the partially damped Camden containing fibreboard has a smaller effect.

4.2 Double leaf partitions

This Section describes sound measurements made on three different types of structural, double-leaf partition. Two of the partitions contained structural steel studs throughout. One of these partitions had an untreated cavity, and acoustic treatment was installed in the cavity of the other partition. These two partitions are intended for use in intermediate-sized studios where heavy loads are to be carried. The third partition tested contained one structural metal-framed leaf and one Shaftwall leaf. The Shaftwall leaf is not capable of supporting heavy loads. This partition is intended for use in intermediate-sized studios in situations where heavy loads can only be carried on one leaf of the partition and the cavity has to be sealed.

Fig. 6 shows the measured sound insulations of two types of structural partition compared with that of a metal-framed double Camden. The first stuctural partition (Fig. 6(a)) consisted of two independent structural metal-framed leaves. The first leaf was constructed as described in the previous Section on single-leaf partitions. The second leaf was built 50 mm from the first leaf. Structural metal studs (100 mm thick) were used in the second leaf, clad with a horizontal layer of 19 mm plank followed by a vertical layer of 12.5 mm thick plasterboard. The second structural partition (Fig. 6(b)) also had a structural metal-.framed first leaf. The second leaf was built 50 mm from the first leaf and was made from 90 mm-thick Shaftwall studs. The inner skin of the Shaftwall leaf was fitted with 19 mm coreboard, and the outer edges of the studs were clad with a layer of 15 mm plasterboard followed by a layer of 9.5 mm plasterboard. This Shaftwall leaf would be suitable for the construction of partitions having heights up to 6 m, although the leaf would not be able to support significant loads.

The partition built from two structural metal-framed leaves (Fig. 6(a)) had higher sound insulations, up to 400 Hz, than those of the partition built from one structural metal-framed leaf and one Shaftwall leaf (Fig. 6(b)). The converse is true above 400 Hz. The partition built from two structural metal-framed leaves has a lower mass-air-mass resonant frequency than the partition containing a Shaftwall leaf, because the effective cavity width between the two structural



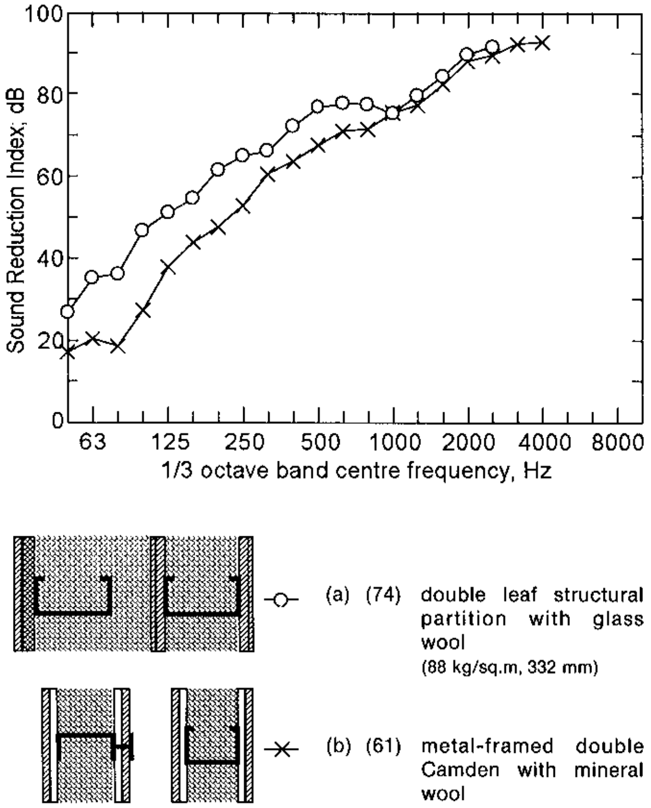
(R_w values are shown in brackets)

Fig. 6 - The sound insulations of double leaf metal-framed partitions.

metal-framed leaves is greater than that between the structural metal-framed leaf and the Shaftwall leaf. This explains the greater sound insulations at lower frequencies of the partition built from two structural metal-framed leaves. The partition with one structural metal-framed leaf and one Shaftwall leaf (Fig. 6(b)) has more mass and smaller cavities than the partition built from two structural metal-framed leaves, which explains the higher sound insulations of the former partition at higher frequencies.

The partition with one structural metal-framed leaf and one Shaftwall leaf (Fig. 6(b)) has a similar sound insulation curve to that of the metal-framed double Camden (Fig. 6(c)). The differences between the two sound insulation curves can be linked with the different internal resonant frequencies of the leaves of the two partitions. The resonant frequencies are affected by the masses of the boards, the different cavity widths and the different levels of damping provided by different types of boards.

The partition having two structural metal-framed leaves has a wide cavity with studs exposed in the cavity. This may make the partition vulnerable to flanking transmission of sound if sound can leak into the cavity at partition boundaries or at door and window details. The fact that the studs are exposed to the cavity may also have implications on the fire integrity of the partition.



(R_w values are shown in brackets)

Fig. 7 - The sound insulations of double leaf metal-framed partitions with treated cavities.

Fig. 7 shows the sound insulations of metal-framed double leaf partitions having acoustically treated cavities. The first leaf of the double leaf partition containing structural steel studs (Fig. 7(a)) was constructed as described in the previous Section on single leaf partitions having treated cavities. The second leaf was built 50 mm from the first, with 50 mm and 100 mm glass wool batts combined in the cavity. The second leaf was clad with 19 mm plank mounted horizontally, followed by a layer of 12.5 mm plasterboard mounted vertically. The metal-framed double Camden (Fig. 7(b)) was of conventional construction, having 75 mm mineral wool batts installed in both leaves.

The installation of glass wool in the cavities of the structural metal-framed partition considerably increased the measured sound insulations of the partition, particularly at lower frequencies. The glass wool absorbs sound that has leaked into the cavities and damps the motion of the boards. The structural metal-framed partition treated with glass wool (Fig. 7(a)) has considerably higher sound insulations, up to 1 kHz, than those of the double Camden treated with mineral wool (Fig. 7(b)). This is probably because the treated structural metal-framed partition is considerably heavier and has more internal damping and absorption than the treated double Camden. The dip at 1 kHz in the sound insulation curve of the structural metal-framed partition may have been related to some construction weakness, although none was identified.

5. CONCLUSIONS

The installation of independent structural metal-framed partitions adjacent to a blockwork wall considerably increased the measured sound insulations above 80 Hz. The achieved levels of sound insulation from the combined masonry and metal-framed constructions should be adequate for the construction of some types of large, low-cost studios.

The sound insulations of structural alternatives to the metal-framed single and double Camdens were slightly higher than those of the Camdens. However, the structural partitions were thicker and heavier than equivalent Camdens. These structural partitions will be suitable for the construction of very low cost studios where significant structural loads must be supported.

The sound insulations were measured of two partitions having 'Shaftwall' second leaves. These

Shaftwall leaves were more complicated and heavier than structural steel second leaves. Although the maximum permissible heights of Shaftwall partitions are large, they would not be able to support significant loads.

The installation of glass wool insulation in the cavities of any of the partitions tested produced large increases in the measured sound insulations. In comparison to the Camden, the plasterboard and coreboard layers in the new partitions are relatively untreated. This is the reason why the increases in sound insulations on installing glass wool in the cavities of the new partitions was greater than that obtained after installing mineral wool in the cavities of Camdens.

6. RECOMMENDATIONS

In large studios where significant structural loads are to be carried and where cost restraints rule out the use of masonry walls, the use of the lightweight partitions described in this Report is recommended. Suitable partitions from those tested should be selected to meet the requirements for maximum partition height, loadbearing ability, cost and achieved level of sound insulation.

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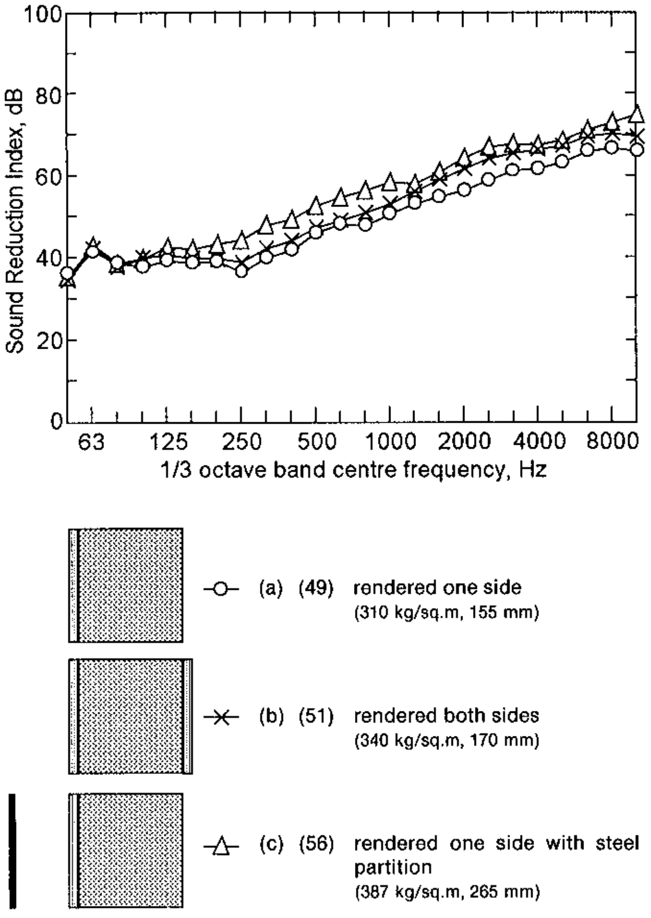
APPENDIX

Sound Insulation Measurements on the Blockwork Wall

For reference, Fig. A.1 shows the measured sound reduction indices of the 140 mm blockwork wall with no associated lightweight partition. Measurements were made with the blockwork wall rendered one side only (Fig. A.1(a)), both sides (Fig. A.1(b)) and one side with a 10 mm steel partition positioned 100 mm from the wall (Fig. A.1(c)). The steel partition was assembled from ten different panels which were bolted together. The steel partition is usually used to blank off the aperture in the receive room walls when making ISO-Standard absorption coefficient measurements in the receive room. The steel partition was in position as part of another series of tests.

The blockwork wall has a level of sound insulation and a shape of insulation curve that would be expected for a single leaf partition of that mass[7]. The addition of render to the second side of the blockwork wall increased the sound insulations above 80 Hz, by 2 dB on average. The level of improvement increased with frequency. The render adds mass to the wall, but more importantly acts as an acoustic seal both for the porosity of the blocks themselves and for any gaps in the mortar joints between the blocks.

The steel partition was a second leaf, effectively decoupled from the blockwork wall. A blockwork leaf having the same mass as the steel partition and the same density as the 140 mm blockwork wall would have a thickness of approximately 40 mm. The steel leaf increases the sound insulation of the partition above 80 Hz, by 6 dB on average.



(R_w values are shown in brackets)

Fig. A.1 - The sound insulations of the 140 mm blockwork wall.